The Musical Scale of the Arabs.

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The Natural Diatonic Scale.

BY

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The views of the Arab scales quoted by Helmholtz and others from Kiesewetter and Villoteau must be recognized as unsound, now that Dr. Land has given a translation of the "Book of Music" of Al Farabi, who died 950 A. D. This proves that musicians demanded different scales for different instruments, although those for the short-necked lute were the most important. This lute had five strings tuned in fourths; for the little finger of the left hand a ligature (fret) was tied around the neck at a quarter-length of the string, so giving a fourth; in the space up to the nut eight other ligatures were tied according to various rules, some by calculating intervals of a tone as the Greeks did, others by bisecting the linear distance between two ligatures: thus arose a scale of twenty-two steps to the octave. But the notes due to the bisections fall in close pairs; so two steps in each tetrachord, or five in the octave, were very short; accordingly later theorists substituted for each pair a third note determined by Greek principles and thus obtained the 17-step scale that has provoked so much controversy. Out of these many-note scales, various short scales or "modes" were selected for musical performance; these modes usually called into exercise only three out of the four fingers, and so had eight notes to the octave.

On the long-necked tambours the ligatures were located by almost entirely different principles, the most important being a "step-by-step tuning," nowhere else described in musical history; as applied on the two-stringed tambour of Bagdad, this principle gave within a total compass of about a minor third a scale of eight notes.

MEDIEVAL ORGAN PIPES AND THEIR BEARING ON THE HISTORY OF THE SCALE. By CHARLES K. WEAD, U. S. Patent Office, Washington, D. C.

The question of the origin and basis of the scale currently accepted by European musicians is now receiving much attention. Some vigorous writers maintain that it is based wholly on harmonic considerations, which apply also with equal force to all peoples who have not been led astray by instruments. I feel most decidedly that this conclusion is a hasty generalization, which has taken account only of a few classes of facts, and especially has ignored the history of the development of the European scale. Both as a contribution to one branch of this history, and as a matter having independent interest, a brief account is to be given of the history of organ-pipe tuning from the earliest times of which we have knowledge of it; no English writer refers to the matter at all, and the few Germans who quote some of the documents of importance here do not consider their bearing on the subject of the scale.

Not much is known of the organs prior to the tenth century. The broad idea of blowing a series of whistles (fistulae) by air compressed by a bellows belongs, as is familiarly known, to classical times, and in our modern histories of the instrument there are various references to organs during the Dark Ages, as one sent to Pepin (757 A. D.), and one to Charlemagne a little later, which last is said to have been the first organ used in a church in the West; but by the close of the eleventh century instruments were in use in several places. Rimbault quotes a bungling, sometimes unintelligible, translation of an XIth century MS., which gives many details of the manufacture of pipes. But a far more important as well as earlier account is found in a MS. of the Xth century, from the German translation of which in Wangemann's Geschichte der Orgel we quote at length. By way of preface it should be noticed that all musical theory underlying these mechanical rules is due to Boethins (c. 525 A. D.), whose somewhat ignorant Latin compilation from Greek musical writers served men admirably during the years when scholasticism demanded, not experimental truth, but authority. So the Greek ideas of three genera, of tetrachords, of ditones instead of our major thirds, of Pythagorean ratios, of divisions of the monochord, etc., are everywhere to be found in these medieval writers. At the same time there is a good deal of variety in their practical ways of teaching the subject, and we shall see how they gradually emancipated themselves from these fettering theories.

This Xth century MS. gives many practical details about the manufacture of organ pipes. They were to be made of thin sheet copper rolled into cylinders about four feet long, all having the diameter of a pigeon's egg (a little over an inch). The lengths were measured from the mouth up. "And now since it is the diatonic genus in which at present for the most part songs move, the pipes are measured as follows: The first, which is smaller and therefore higher than all the rest, must be divided into eight parts, and by an eighth part of the first must the second be greater than the first, in order that they may differ by a tone. Just so the third must be greater than the second by an eighth part, and a tone lie between them. Then it must be so arranged that the fourth is greater than the first by the third part of the first, so that it differs from the first by a fourth, and from the third by a half-one. And the fifth must be greater than the first by a half of the first, so that it forms the pure fifth to it, but a tone with the fourth. The sixth must be greater than the fifth by an eighth of the fifth, and have a tone between them. The seventh must be greater than the fourth by a third part of the fourth in order to form with it a fourth, but a half-tone to the sixth. The eighth has the double length of the first, and is distant from it by a pure octave, which is always made up of a fourth and a fifth. The same operation as in the measurement for the second pipe is to be repeated to determine the series from the octave up in the order that we have given. With the seven tones of the octave described one can by rising and falling produce every song." Then follow details of mechanism—several pipes in unison or octaves, sometimes as many as five or ten, might be arranged to each

valve, the longer pipes being at the player's right hand. Connected to the valves by iron wires were certain wooden plates (keys?) bearing the "letters of the alphabet written twice, thus :

A B C D E F G A B C D E F G H

in order that the player may more quickly see which plate he should strike."

A second rule for pipe lengths is then given, as if this anonymous MS. was a collection from various sources ; it was thus : "He who would know the measures and construction of an organ must first of all imagine eight pipes having the same length and thickness, but all larger above than below (i. e., conical). Then take the first, which may be long or short, at pleasure ; to find the relation of the second to it divide the first into nine parts and make the second equal to 8 : 9 of the first ; similarly divide the second pipe into nine parts, and give the third again 8 : 9 of the second; to get the correct measure of the fourth pipe give it 3 : 4 of the first. The fourth pipe divide into nine parts, and the fifth must be in length 8 : 9 of it, as well as the sixth 8 : 9 of the fifth. The seventh again is 3 : 4 of the fourth, while the eighth is 8 : 9 of the seventh. When these eight are ready one goes, in the same way as from the first to the eighth, from the eighth to the fifteenth, the octave of the eighth, and from the fifteenth to the twenty-second, the octave of the fifteenth." To each valve there are to be arranged two longer pipes and a shorter one placed between them "that the three pipes may give a consonance, the so-called octave ;" apparently the compass was as before only two octaves. Wangemann seems to overlook the fact that these two rules give totally different successions, for the first is a descending scale—increasing pipe lengths ; the second an ascending scale. The first nominally gives a series of intervals approximately the same as from our a down to A, while the second gives approximately G to g, thus :

	G	A	B	C	D	E	F	G	a
First Rule	—	2	$\frac{16}{9}$	$\frac{27}{16}$	$\frac{3}{2}$	$\frac{4}{3}$	$\frac{81}{64}$	$\frac{8}{9}$	1
	'	1	$\frac{8}{9}$	$\frac{27}{32}$	$\frac{3}{4}$	$\frac{2}{3}$	$\frac{81}{128}$	$\frac{9}{16}$	$\frac{1}{2}$
	—								
Second Rule	1	$\frac{8}{9}$	$\frac{64}{81}$	$\frac{8}{9}$	$\frac{2}{3}$	$\frac{16}{27}$	$\frac{9}{16}$	$\frac{1}{2}$	

If these two scales have any note in common they agree throughout, for each number in the last line is 8 : 9 of the number directly above it.

But any one who has the slightest knowledge of organ-pipe construction knows that all these intervals would in practice be found quite flat, the shorter pipes being relatively too long, and even the octaves sounding together in the way just described would be very unsatisfactory. So it is interesting to see how early the inadequacy of these rules was recognized.

A MS. of the Xth century attributed by Gerbert to Hucbald gives the following rule, which Wangemann, who quotes it along with those just given, strangely says, offers nothing new : "If the pipes are of equal diameter and the greater contains the less twice in its length and in addition its diameter they will mutually sound the consonance diapason [octave]. * * If the greater pipe contains the less a whole time and a third part

of its length besides, and also a third part of the diameter of the hollow [i. e., of the internal diameter], they will sound a diatessaron [fourth].'' Other ratios given are, for the double diapason four times the length of the shorter pipe plus three diameters; for the diapenute, or fifth, one and a half lengths and half the diameter; for a tone, one length and an eighth; and for a semitone, one length and a sixteenth. These rules give intervals, but not directly a scale in which the semitones are definitely located.

But Hucbald has several other rules, one of which gives the succession nominally as from C to c, thus:

1 $\frac{8}{9}$ $\frac{64}{81}$ $\frac{3}{4}$ $\frac{2}{3}$ $\frac{16}{27}$ $\frac{128}{243}$ $\frac{1}{2}$.

In one passage he says the first (highest) pipe should have a length eight times its diameter.

Odo in the same century gives clearly a different idea of getting out his ratios, though the results are the same, and he brings in both b and b flat. He says: "In the measures of pipes there are the notes

C D E F G a ♮ c .

"The length of low C is to be taken at pleasure; this is divided into four parts and one part being subtracted leaves the pipe F." His further details may be condensed to a line thus:

G=$\frac{2}{3}$ C; D=$\frac{4}{3}$ G; a=$\frac{2}{3}$ D; E=$\frac{4}{3}$ a; ♮[=b]=$\frac{2}{3}$ E; b[=b♭]=$\frac{3}{4}$ F.

"Further, the skilful musician observes that these measures are established by fourths and fifths," quite in the spirit of nineteenth century tuners, only he worked by measure, they by ear.

By far the fullest account of rules for pipe-lengths is given in the tractate De Musica by one of the brothers of St. Gall, written in Old High German in the same tenth century. The MS. Gerbert used was very imperfect, and Riemann has corrected his readings by the aid of the fine Leipzig Codex. Not the least important point is the frequent implication that the instruments were to guide the voice; so rules are first given for the lyre and psaltery; but it is said to be difficult to get the length of strings right, for if too long they are scarcely sonorous and the tone is poor, while if too short the higher tones are thin. But he who measures off organ pipes avoids these difficulties. "It is said that a pipe for the first letter [A] one ell in length from its lip up is too short, and one of two ells is too long; but those between the two having a length of an ell and a half are suitable." The only figures I find for the ell of St. Gall (unfortunately of much later date) give it as almost exactly 24 English inches; so this lowest pipe would have been about 36 inches long, and have given a note between d and f (on the bass staff) of our modern pianos. The uncertainty is because we do not know the diameter of the pipe which was to be "so wide as pleases you." The rules, which are so long that it might be tedious to quote them, give an ascending scale, with both minor seventh (called synemenon) and major, all corrected for influence of diameter nearly in the same way as stated by Hucbald; thus

"take from the length of the first pipe the eighth part of its width and divide it from the point down to the lip * * * into nine parts of equal size; give eight of these to the second pipe; this is its length from the tip up."

The same Leipzig Codex contains a curious rule that makes the ratio for a tone 7 : 8 instead of 8 : 9. The author starts from A and ascends in pitch, so obtaining results that may be tabulated as follows:

His notation	A	.	B	.	C	D	.	E	.	F	.	G	a
Modern notation	A	.	B	C	♯	D	.	E	F	♯	G	♯	a
Or	C	.	D	.	E	F	.	G	.	A	.	B	C
	1	.	$\frac{7}{8}$	.	$\frac{49}{64}$	$\frac{3}{4}$	.	$\frac{21}{32}$	.	$\frac{147}{256}$	.	$\frac{1029}{2048}$	$\frac{1}{2}$

Riemann treats this ratio 7 : 8 as the rough equivalent of Notker's ratio 8 : 9 together with this correction for diameter; but this is inadmissible, for the fourth and octave are not corrected and so the two semitones are almost vanishingly small, or rather what should be the lower note, comes out the higher one!

Aribo, in the next century, gives Notker's rules, and others due to Monk Wilhelm with corrections based on different fractions of the diameter. And many more rules might be quoted.

Coming to more recent times, there is a little to be found in Father Kircher's voluminous Musurgia Universalis, published in 1650. He says the ratio of circumference to length of organ pipes varies very much, as from one-fourth to three-fifths; two-fifths was perhaps most usual (giving a diameter one-eighth of the length as stated by earlier writers). His lengths follow the familiar modern ratios, 1 : 2, 2 : 3, 3 : 4, 4 : 5, 8 : 9. He does not refer to any correction for diameter, which would be of large importance with such large pipes, nor does he speak of tuning the pipes after they are made. A century more shows a marked advance; for in the great book of Bedos de Celles, "L'art du Facteurs d'Orgues," Paris, 1766, while rules are given for fixing the pipe-lengths, proceeding by fourths and fifths, there are also directions for tuning by cutting the pipes off afterward to the exact desired pitch, and in the plates there are figures of tuning-cornets such as are used to-day. Lastly, in the great Encyclopédie (1750), under "Diapason," it was directed that to the computed length as given by such rules as the above some inches shall be added to allow for contingencies of tuning.

These citations are enough to show how slowly our ancestors, starting from the purely mechanical-mathematical scale inherited from the Greeks, and practically fitted only for a thin-stringed monochord, progressed to the series of notes of to-day, that is independent of any particular instrument. Historically, development of the scale has gone along with the development and perfection of instruments, first of the organ and then of the piano. In the organ the wind supply needed great improvements before a steady tone could be produced, and it was not till the invention of the wind-gauge in 1677 that this was fairly accomplished. Meantime other improvements had been going on; the keys were narrowed, the

many pipes to a single key were distributed to registers, and pedals and black keys had been introduced. But all the time that the ideas of polyphony and incipient harmony were growing, the king of instruments was not fitted to furnish a single interval that would be at all acceptable to-day. In fact Praetorius, who died in 1621, thirty years after Palestrina's death and seventy-five years after Luther's death, says one reason for the slow development of harmony was that "the tones and semitones were not turned correctly, and therefore the instruments or organs were not turned so 'justly' as at present." The errors of the old rule were very great; two pipes of 36 and 18 inches length above the lip and $2\frac{1}{4}$ inches diameter, according to Kircher's proportion, would not be an octave apart, but only a little over ten semitones, as C–A; perhaps the early pipes were slimmer and the error less, so the corrected rule might give a fair approximation to correct intervals; still the correction is not more than half or three fifths of that required by the rules of the famous modern French organ builder, Cavaillé-Coll.

There is one more stage in the history of our scale. After the organ had been so far perfected that any desired intonation (*e. g.*, just, mean-tone or equal temperament) could be given to it, keyed-stringed instruments were developed with not a little deliberate imitation of organ ideals, as those know who saw the Steinert collection at the Chicago Exposition. As the logical outcome of the demand on the part of the growing harmony for freer modulation into all keys there was a modification of the old Pythagorean and harmonic tunings, as well as of the mean-tone temperament, finally resulting in the equal temperament. This could be carried out conveniently on the stringed instruments; it was more needed for the kind of music written for them, and the short duration of their sounds rendered the deviations of the tuning from perfect concords less offensive to the ear than when it was practiced on the long-drawn notes of the organ. But musicians found it unsatisfactory to try to maintain several standard scales, so the clavichord and piano have in spite of bitter opposition, forced their peculiar scale upon the European musical world, till orchestra, voices, and finally the organ have, with practical unanimity, surrendered to it. Of course this is a "survival of the fittest," but the statement only means the fittest for a particular environment; for other environments it would not necessarily be the fittest; *e. g.*, that of an Oriental or savage musician, of a string quartette or of Europeans a century hence.

Finally it is to be observed that instruments have been the guides to the voice in all these ages under consideration. Guido, who died in 1050, taught his boys the intervals by the aid of the monochord, which he improved for this purpose. In later times the organs served a similar purpose, as appears from the remark of Praetorius, who says: "That the compass remained narrow for so long a time is because the organ was used only to accompany choral singing, and no great range was required, for harmony was unknown," and he distinctly says that only the bare choral in one part was performed on them. Even to-day what pupil learns to sing

intervals correctly except by directly or indirectly imitating an instrument? As instruments have developed, both the scales embodied in them and the ideas of musicians concerning the scale have changed, responding to distinctly traceable influences; and there is no hint in the long history that the "harmonic consciousness," on which to-day much stress is laid by some writers, has ever failed to content itself with the scale familiar to it, however wide the departures from a true harmonic scale. So if in the fields where harmony has won practically all its triumphs there is no proof of a scale-making "harmonic consciousness," may we not ask for substantial evidence that it exists among peoples who have no harmony? And may we not expect that ample explanation of the facts alleged in support of this view will be found when all the circumstances of the investigation are made known?

This brief presentation of one phase of musical history should convince the student that the opposing views regarding the basis of the scale so dogmatically presented by extreme physicists or extreme musicians are alike inadequate, because they disregard the historical elements of the problem.

NOTE.—The historical authorities for the principal statements made above are as follows: Rimbault, E. F.: The History of the Organ, London, 1870: Wangemann, O.: Geschichte der Orgel, Demmin, 1880, p. 66, 69, 70, 91. Gerbert, M.: Scriptores ecclesiastici de musica sacra, 1784, as reprinted in Migne's Patrologia Latina, Vols. 131, 132, 133, under the names of Hucbald, Odo, Notker, and Aribo. Reimann, H.: Studien zur Geschichte der Notenschrift, Leipzig, 1878, p. 298. The argument for the "harmonic consciousness" is strongly put by the late Professor J. C. Fillmore in Omaha Indian Music, Cambridge, 1893.

THE NATURAL DIATONIC SCALE. BY CHARLES K. WEAD.

This paper gives an account of the history of the three words in the title. In the mediaeval tables those hexachords involving the use of b-molle (b ♭) were called *molle;* those involving b-dur (b natural) were called *dur;* and those that did not involve either b, but applied Guido's six syllables to the letters in their natural order from A up, were called *natural* hexachords; the other things and names have lost interest for modern musicians, and the so-called "natural" series remains, and retains the name. "Diatonic" refers generically to those tunings of the intermediate strings of the Greek lyre, located between E and A, in which the strings were most "on the stretch," and so gave their highest tones, and specifically to the highest of these tunings, the one giving substantially the same succession as our E, F, G, A. "Scale" is not found in use till after 1500; the old word for the series of sounds was *systema;* for the notes on paper, *diagram. Scala* at first referred to the tables of hexachords, then to notes arranged on lines and in spaces, and finally to the series of sounds, which is now the exclusive meaning.